Staff Technical Conference on Increasing Real-Time and Day-Ahead Market Efficiency through Improved Software (Docket No. AD10-12-001)

Federal Energy Regulatory Commission
Commission Meeting Room, 888 First Street NE, Washington, DC
Agenda (abstracts attached below)

Tuesday, June 28, 2011

*anticipated speaker

8:15 AM Arrive and welcome

8:30 AM Session A

*Rana Mukerji, New York ISO (Rensselaer, NY)
NYISO Unit Commitment Modeling and Mixed Integer Evaluation

*Michael Ward, PJM Interconnection, L.L.C. (Norristown, PA)
Resource Commitment and Dispatch in the PJM Wholesale Electricity Market

*Eugene Litvinov, ISO New England (Holyoke, MA)
Study of Two-Stage Robust Unit Commitment

10:00 AM Break

10:15 AM Session B

*Li Zhang, *Paul Gribik, *Tengshun Peng, Midwest ISO (Carmel, IN)
A Probabilistic Optimization Reliability Assessment Commitment Framework

*Jim Waight, Siemens Energy (Minnetonka, MN)
Deregulated Market Communication: Common Information Model for Day-Ahead and Real-Time Markets

*Edward Rothberg, Gurobi Optimization (Houston, TX)
Linear and Integer Programming - Powering Unit Commitment Models

11:45 AM Lunch

1:00 PM Session C

*Alex Papalexopoulos, ECCO International (San Francisco, CA)
A Focus on Improving Performance of the Day-Ahead Market – A Market Participant Perspective

*Chien-Ning Yu, Ventyx (Santa Clara, CA); Sainath M. Moorty, ERCOT (Austin, TX)
Improving Day-Ahead Market Efficiency through Advanced Combined Cycle Modeling

*Victor Zavala, Argonne National Laboratory (Argonne, IL)
On the Convergence of Day-Ahead and Real-Time Electricity Markets

*Robert Entriken, Electric Power Research Institute (Palo Alto, CA); Janusz Bialek, Chris Dent, Durham University (Durham, United Kingdom); Pravin Varaiya, UC Berkeley (Berkeley, CA); Felix Wu, University of Hong Kong (Honk Kong)
Risk Limiting Dispatch

3:00 PM Break

3:15 PM Session D

*Warren Powell, Princeton University (Princeton, NJ)
Stochastic Models for Energy Resource Planning: Sorting Through the Jungle of Stochastic Optimization

*Zhi Zhou, *Audun Botterud, Jianhui Wang, Argonne National Laboratory (Argonne, IL)
Probabilistic Wind Power Forecasting in Electricity Market Operations: a Case Study of Illinois

*Anthony Papavasiliou, UC Berkeley IEOR Dept. (Berkeley, CA)
Multi-Area Stochastic Unit Commitment for High Wind Penetration in a Transmission Constrained Network

*Eric Krall, Richard O'Neill, Federal Energy Regulatory Commission (Washington, DC)
RTO-Scale Unit Commitment Test Cases

5:15 PM Adjourn

Issued June 6, 2011. Agenda subject to change. Check http://www.ferc.gov/industries/electric/indus-act/market-planning.asp for the most recent agenda.

Wednesday, June 29, 2011 *anticipated speaker

8:15 AM Arrive and welcome

8:30 AM Session A

*Diego Klabjan, Northwestern University (Evanston, IL)
Stochastic Unit Commitment with DR by Approximate Dynamic Programming

*Christian Hewicker, Ralph Masiello, KEMA (Bonn, Germany; Chalfont, PA)
Integrating Gas and Electric Infrastructure in System Planning and Market Operations

*Erik Ela, NREL (Golden, CO)
Market Design Simulations with High VER Penetrations

10:00 AM Break

10:15 AM Session B

*Ralph Masiello, KEMA (Chalfont, PA); Rana Mukerji, Jim Gallagher, New York ISO (Rensselaer, NY)
Integrating Retail Dispatchable Demand Response and Dynamic Pricing in the Wholesale Markets

*Dhiman Chatterjee, Midwest ISO (Carmel, IN)
Addressing Real-Time Price Volatility in MISO Markets

*Petar Ristanovic, California ISO (Folsom, CA)
Managing Renewable and Distributed Resources' Intermittencies: Future Market and Software Enhancements

11:45 AM Lunch

1:00 PM Session C

*Simon Tam, PJM Interconnection, L.L.C. (Norristown, PA)
Real-time Security-Constrained Economic Dispatch and Commitment in the PJM: Experiences and Challenges

*Slava Maslennikov, ISO New England (Holyoke, MA); *Kwok W. Cheung, Alstom Grid, R&D (Redmond, WA)
Utilization of Adaptive Transmission Rates in Dispatch

*Yonghong Chen, Paul Gribik, Midwest ISO (Carmel, IN)
Incorporating Reserve Deployment Impact on Transmission Constraints into Co-optimization of Energy and Ancillary Service Procurement

*Robert Entriken, Electric Power Research Institute (Palo Alto, CA); Taiyou Yong, Eversource Consulting (Folsom, CA)
Technique for Reserve Determination with Consideration for Conventional and Emerging Technologies: Enhancement of Stochastic Optimal Power Flow

3:00 PM Break

3:15 PM Session D

*Marianna Vaiman, V&R Energy (Los Angeles, CA)
Determining Optimal Mitigation Measures to Improve Transmission System Reliability in Real-Time

*Daniel Bienstock, Columbia University (New York, NY)
Online Control of Cascading Power Failures

*Pablo Ruiz, Alex Rudkevich, Charles River Associate (Boston, MA); Justin M. Foster, Michael C. Caramanis, Boston University (Boston, MA)
Tractable Transmission Topology Control

*Thomas Dautel, Richard O'Neill, Federal Energy Regulatory Commission (Washington, DC)
AC Optimal Transmission Switching

5:15 PM Adjourn

Thursday, June 30, 2011 *anticipated speaker

8:15 AM Arrive and welcome

8:30 AM Session A

*Cong Liu, Jianhui Wang, Argonne National Laboratory (Argonne, IL)
Improving Static Security and Preventing Multiple Solutions in Transmission Switching

*Kwok Cheung, Alstom Grid (Redmond, WA)
Optimal Transmission Switching: A Practical Assessment

*James Ostrowski, Jianhui Wang, Argonne National Laboratory (Argonne, IL)
Symmetry and Network Connectivity in Transmission Switching

10:00 AM Break

10:15 AM Session B

*Mark Lively, Utility Economic Engineers (Gaithersburg, MD)
Real-Time Physical Markets—Within As Well As Between and Among Control Areas

*Linda Ness, Telcordia Applied Research (Piscataway, NJ)
Fast Multiscale Algorithms for Representation and Analysis of Streaming Data

*Marija Ilić, *Jeffrey Lang, New Electricity Transmission Software Solutions (NETSS), Inc. (Sudbury, MA)
Experience with AC Extended Optimal Power Flow (AC XOPF) on the New York System

11:45 AM Lunch

1:00 PM Session C

*Vadim Shapiro, *Jeff Knollenberg, Statistics & Control, Inc. (West Des Moines, IA)
Dynamic Performance-Based Dispatch of Power Generation

*Nicolas Omont, Artelys (Paris, France)
Towards the Implementation of Flow-Based Market Coupling in the Central Western Europe Region

*Jinxiang Zhu, ABB Inc. (Raleigh, NC)
Day-Ahead Market Challenges to Production Simulation Tool

2:30 PM Break

2:45 PM Session D

*John McNally, A123 Systems (Chesterfield, MO)
Increased Generator Flexibility through Distributed Software and Storage Assets

*Jerry Dempsey, Open Access Technology International (Minneapolis, MN)
Improving Real-Time and Intra-Hour Trading/Scheduling in Congested Bilateral Markets

*Rouquia Djabali, Epex Spot sa (Paris, France)
Central West Europe Day-Ahead Market Coupling Algorithm

*Anya Castillo, Richard O'Neill, Michael Higgins, Federal Energy Regulatory Commission (Washington, DC)
Computational Approaches to the AC Optimal Power Flow (OPF) Problem

4:45 PM Adjourn

Staff Technical Conference on Increasing Real-Time and Day-Ahead Market Efficiency through Improved Software

Abstracts

Tuesday, June 28

Session A (Tuesday, June 28, 8:30 AM)

*Rana Mukerji, Sr. Vice President, Market Structures, New York ISO (Rensselaer, NY)
NYISO Unit Commitment Modeling and Mixed Integer Evaluation

Overview of the NYISO unit commitment scheduling process and efforts to integrate mixed integer evaluation.

*Michael Ward, Manager, Day-Ahead Market Operations, PJM Interconnection, L.L.C. (Norristown, PA)
Resource Commitment and Dispatch in the PJM Wholesale Electricity Market

This presentation will provide an overview of the size and scope of the PJM wholesale electricity market and the scheduling and operational challenges we expect to encounter in the future with increased penetration of intermittent and distributed resources. It will also provide a brief overview of the development and implementation of the mixed-integer programming-based unit commitment and dispatch programs in the PJM market and will describe the benefits achieved to date.

*Eugene Litvinov, Senior Director, ISO New England (Holyoke, MA)
Study of Two-Stage Robust Unit Commitment

Unit Commitment faces new challenges as the supply and demand uncertainty increases dramatically due to the integration of variable generation resources. To meet these challenges, we propose a two-stage robust unit commitment model, which yields an "immunized against uncertainty" commitment solution. The model is applied to a real-world large scale power system operated by the ISO New England. The numerical study compares the proposed approach with the traditional reserve adjustment practice, and illustrates the economic and operational advantages of the robust unit commitment. We find that by properly setting the level of conservatism, the robust model exhibits sizable savings on both average dispatch and total costs. Furthermore, the proposed approach significantly reduces the volatility of the dispatch cost, thus, improves the real-time reliability of the power system operations. Compared to the reserve adjustment, the robust model also shows resilient performance under different probability distributions of load.

Session B (Tuesday, June 28, 10:15 AM)

*Li Zhang, Manager, Market Systems Design and Evaluation, Midwest ISO (Carmel, IN)
*Paul Gribik, Sr. Director, Market Development and Analysis, Midwest ISO (Carmel, IN)
*Tengshun Peng, Principal Market Assessment Engineer, Midwest ISO (Carmel, IN)
A Probabilistic Optimization Reliability Assessment Commitment Framework

The purpose of the Reliability Assessment Commitment (RAC) process is to ensure that sufficient capacity is committed to meet anticipated Real-Time demand for energy and ancillary services. We propose models for commitment and dispatch processes in which system requirements are subject to uncertainty. The purpose is to develop a generalized probabilistic optimization based framework which can improve the RTO's ability to operate reliably and economically. We can formulate a very comprehensive model in which supply, demand and transmission elements can be modeled as random processes (load, resource availability, interchange level, etc). These random processes are modeled as Markov processes in which the probability of a given process taking a particular value at a given time depends upon the values the demand had in the past (the state at the previous time interval). At any time, the model makes commitment and dispatch decisions to minimize the operating costs at the time and the expected costs of future operations. All operating costs (start-up, no-load and dispatch costs) are considered. This optimization model would not be computationally tractable due to its size. To reduce the size, we can make simplifying assumptions. One possible assumption is that slow start resources must be committed before uncertainties are resolved and that fast start resources (and dispatch of all committed resources) will be scheduled after uncertainties are resolved. We can still seek to minimize expected operating costs. However, the tree has been reduced to two stages. In the first stage, slow start resources are committed when uncertainty is still large. In the second stage, we commit fast start resources and dispatch resources once uncertainty has been resolved. In essence, the second stage consists of a sequence of iterative commitment and dispatch processes. This simplified probabilistic recourse formulation is more practical for RTO size problems, and different practices can be explained under this framework with assumptions. We can develop a formulation that considers costs in a fashion similar to the way that current RAC formulations only consider the commitment costs of resources (start-up costs and costs of dispatching committed resources at minimum output). We can do this by setting the the probabilities of each branch in the two stage formulation to zero to remove the costs of committing fast start resources and dispatching committed resources above minimum output. The formulation retains the constraints in each of the second stage branches. The resulting formulation minimizes the cost of committing slow start resources (start-up cost and cost of dispatching at minimum output) so that we have the flexibility to commit fast start resources and dispatch all committed resources to meet a range of requirements in each possible outcome.. This expands today's RAC which only commits to meet requirements under a single forecast, and uses operating reserves to cover uncertainties.

*Jim Waight, Product Lifecycle Manager, Siemens Energy (Minnetonka, MN)
Deregulated Market Communication: Common Information Model for Day-Ahead and Real-Time Markets

Since the last FERC Technical Conference in June 2010, the International Electrotechnical Commission, Technical Committee 57 (TC 57) Working Group 16 has

made significant progress in drafting an interface model for Day-Ahead Markets and Real-Time Markets characterized by bid-based day-ahead unit commitment by a market operator, and settlement with locational marginal prices. This interface model may be used to develop standard interfaces to market clearing software. Once these international standards are complete, it will be possible for utilities and market operators to purchase unit commitment software from vendors who comply with the standard, and to then integrate the new software with their existing systems with relatively modest software integration effort. The resulting competition in the sourcing of unit commitment software should help promote overall market efficiency. The work of TC 57, and its working groups is also known as the IEC Common Information Model (CIM)

*Edward Rothberg, Chief Operating Officer, Gurobi Optimization (Houston, TX)
Linear and Integer Programming - Powering Unit Commitment Models

Linear and integer programming solvers are the engines that power optimization models for unit commitment problems. As the capabilities of these solvers continue to improve, this has implications for the type and scale of problem that can be solved. This talk will discuss recent progress in LP and MIP solvers.

Session C (Tuesday, June 28, 1:00 PM)

*Alex Papalexopoulos, President and CEO, ECCO International (San Francisco, CA)
A Focus on Improving Performance of the Day-Ahead Market – A Market Participant Perspective

Improvements in methodologies and software modeling are required to provide sufficient simulation and analysis capabilities to Market participants to successfully participate in competitive centralized wholesale markets. In this presentation we'll present our experience in modeling both supply and demand resources to clear the market. We will discuss SmartGrid, the impact of managing multiple resources, generation, storage and DR. We'll conclude with the information requirements Market Participants need to model market conditions.

*Chien-Ning Yu, Consulting Engineer, Ventyx, An ABB Company (Santa Clara, CA)
Sainath M. Moorty, Principal, ERCOT (Austin, TX)
Improving Day-Ahead Market Efficiency through Advanced Combined Cycle Modeling

ERCOT has successfully moved from a zonal market to an advanced nodal market since December 2010. Combined cycle plants constitute a significant share of its total installed capacity. Accurate modeling and optimal scheduling of combined cycle plants is one of the key innovations contributing to the efficiency of the EROCT nodal market. The advanced model enables optimal configuration of combined cycle plants in the day-ahead market scheduling. The complex dependency between the various physical components that make up a combined cycle plant is addressed through a configuration-based model combined with a state transition matrix. Advanced features of the model will be discussed and future direction will be presented.

*Victor Zavala, Assistant Computational Mathematician, Argonne National Laboratory (Argonne, IL)
On the Convergence of Day-Ahead and Real-Time Electricity Markets

We will present novel concepts on dynamic electricity markets and stochastic optimization that have the potential of enabling a closer convergence of day-ahead and real-time electricity prices. In particular, we propose a framework to filter out spurious bids and anticipate price volatility and stability issues as uncertainty of loads and renewables unfolds in the future. This can be used to clear ramp capacity and spinning reserves more efficiently and prevent market manipulation and ultimately prevent market volatility.

*Robert Entriken, Senior Project Manager, Electric Power Research Institute (Palo Alto, CA)
Janusz Bialek, Professor, Durham University (Durham, United Kingdom)
Chris Dent, Research Fellow, Durham University (Durham, United Kingdom)
Pravin Varaiya, Professor, UC Berkeley (Berkeley, CA)
Felix Wu, Chair of Electrical Engineering, University of Hong Kong (Honk Kong)
Risk Limiting Dispatch

A new operating paradigm is needed to take advantage of new technologies and opportunities. This presentation describes a scheduling methodology for diverse resources that meets system reliability standards, has high capacity utilization, accounts for risks of intermittent resources and uncertain events, and incorporates the new information and capabilities of a smart grid. We show the benefits of additional monitoring and settlements to balance power as approaching real time.

Session D (Tuesday, June 28, 3:15 PM)

*Warren Powell, Professor, Princeton University (Princeton, NJ)
Stochastic Models for Energy Resource Planning: Sorting Through the Jungle of Stochastic Optimization

Energy systems introduce design and control problems that have to be solved in the presence of different types of uncertainty. These include locating and sizing storage devices and wind farms, controlling storage systems, stochastic unit commitment, load curtailment and dynamic pricing. The most subtle dimension that arises when modeling and solving these problems is properly capturing the flow of information, which arises whenever we have to deal with uncertainty. I will use examples from energy storage and unit commitment to illustrate the significant errors that can arise when information is not modeled correctly. I will then address the challenge of developing practical tools for making decisions under uncertainty. This field can seem like a jungle of competing algorithmic strategies. I will streamline the field by reducing all the major algorithmic strategies to four fundamental classes of policies. I will then illustrate each of these policies in the context of specific problems such as energy storage, load curtailment, unit commitment and energy resource planning. In the process, I will try to provide insights into how to choose the best strategy for a problem.

*Zhi Zhou, Postdoctoral Researcher, Argonne National Laboratory (Argonne, IL)
*Audun Botterud, Energy Systems Engineer, Argonne Natural Laboratory (Argonne, IL)
Jianhui Wang, Computing Engineer, Argonne National Laboratory (Argonne, IL)
Probabilistic Wind Power Forecasting in Electricity Market Operations: a Case Study of Illinois

In this study, we demonstrate how a system operator can use advanced forecasting and unit commitment methods to handle the uncertainty and risk from renewable resources. We provide a simulation framework to analyze the unit commitment and dispatch of energy and operating reserves in a power system with high levels of variable renewable resources. Specifically, we discuss how probabilistic wind power forecasts can serve as an important tool to efficiently address wind power uncertainty in the operations of power systems and electricity markets. We develop a kernel density forecasting model with a time-adaptive quantile-copula estimator to predict the probability density function of wind power for different look-ahead hours. A set of scenarios is derived as input to a stochastic unit commitment model. Results are compared to deterministic unit commitment models, where we use the quantiles of the wind power distribution in the probabilistic forecasts to derive dynamic operating reserve requirements. The probabilistic forecasting and unit commitment models are applied to the Illinois power system to study the effects of wind power forecasting uncertainty and reserve margin requirements to accommodate wind power in the operation of the system. The results show that the use of probabilistic forecasts can contribute to improving the system performance in terms of cost and reliability.

*Anthony Papavasiliou, PhD Candidate, UC Berkeley IEOR Dept. (Berkeley, CA)
Multi-Area Stochastic Unit Commitment for High Wind Penetration in a Transmission Constrained Network

We present a stochastic unit commitment model for studying the impact of large-scale wind integration in power systems with transmission constraints and system component failures. We develop a multi-area wind power production model that represents wind production in various locations of the power network. We use a scenario selection algorithm inspired by importance sampling in order to select wind power production and element failure scenarios that are input to our stochastic unit commitment formulation and we provide a dual decomposition algorithm for solving the resulting large scale mixed integer program. We test the resulting unit commitment policy on a 225 bus model of California with 124 generators and 375 transmission lines and demonstrate that it outperforms common reserve rules.

*Eric Krall, Operations Research Analyst, Federal Energy Regulatory Commission (Washington, DC)
Richard O'Neill, Chief Economic Advisor, Federal Energy Regulatory Commission (Washington, DC)
RTO-Scale Unit Commitment Test Cases

Test cases can be used to benchmark the performance and solution characteristics of proposed optimization techniques for generator commitment and dispatch. This talk will discuss the development of a data set and model for an RTO-scale unit commitment test case.

*anticipated speaker

Wednesday, June 29

Session A (Wednesday, June 29, 8:30 AM)

*Diego Klabjan, Associate Professor, Northwestern University (Evanston, IL)
Stochastic Unit Commitment with DR by Approximate Dynamic Programming

It is well recognized that the unit commitment problem in a day-ahead market exhibits many uncertainties, especially in the presence of renewable energy generation. We present a model that simultaneously captures many stochastic aspects: solar and wind generation, and unknown load requirements. In addition, we capture economic DR through bids and uncertain load shifting of DR bidders. Potential mismatch of load and supply is captured by probabilistic or chance constraints imposing very low probability of dispatching spinning reserves. We use approximate dynamic programming with progressive hedging as a solution methodology with many novel enhancements. The appeal of such a methodology is its generality and ability to handle various uncertainties without generating scenarios a priori. The model and methodology has been tested and validated on several data sets by using realistic solar and wind outputs, and best guesses for parameters of 'conventional' generators. DR attributes were generated based on educated estimates. Major findings will be presented together with sensitivity analyses.

*Christian Hewicker, Director, KEMA (Bonn, Germany)
Ralph Masiello, Sr. Vice President, KEMA (Chalfont, PA)
Integrating Gas and Electric Infrastructure in System Planning and Market Operations

The European Climate Foundation 2050 project in its second phase is examining the combined gas and electric infrastructure in the EU under high renewable penetration scenarios. The ability of the gas infrastructure to support conventional generation back-up for renewables is of particular concern. This paper describes the development of market and planning software that integrates gas and electric operations and planning and in particular how contingencies in gas supply can affect electricity markets and operations.

*Erik Ela, Engineer, NREL (Golden, CO)
Market Design Simulations with High VER Penetrations

The National Renewable Energy Laboratory has developed a high resolution power system model, the Flexible Energy Scheduling Tool for Integration of Variable Generation (FESTIV). FESTIV models security-constrained unit commitment (SCUC), security-constrained economic dispatch (SCED), and automatic generation control (AGC) with user input on how all of these sub-models are to be run. Therefore, the systems can easily match the exact design of current ISO/RTO markets in terms of how often the SCUC, SCED, and AGC are run, what interval resolution they use, what horizon they are optimized over and how different constraints can be taken in. One of the key applications of this model is to analyze how different modeling programs affect the operating reserve requirements of a system with high VER penetrations. For instance, a system with 5-minute dispatch and 60-minute horizon may need different reserve requirements than a system with 15-minute dispatch and 120-minute horizon. Each of the sub-models communicates with each other as would be done in practice and therefore the

AGC has to know what the past SCED results are and vice-versa. This type of model allows for studies to not only analyze how VER penetrations impact the system, but how different market designs may impact these high VER penetrations systems as well. This can be used to test how market designs get integrated into ISO/RTO day-ahead and real-time market design and software to determine whether these changes should be made in practice. The FESTIV model differs from some of the existing commercial production cost models since it better replicates actual ISO/RTO operation, and measures reliability impacts rather than simply production costs. Ultimately, the imbalance (ACE), line flow exceedance, and even voltage violations can be analyzed at the highest time resolution, the frequency at which AGC is run. These reliability results are highly dependent on how the other sub-models are working. The presentation will discuss the model, give some examples of how market design changes impact results without changing inputs, and then discuss how NREL plans on using this tool to analyze how operating reserve requirements may be affected with high VER penetration systems.

Session B (Wednesday, June 29, 10:15 AM)

*Ralph Masiello, Sr. Vice President, KEMA (Chalfont, PA)
Rana Mukerji, Sr. Vice President, Market Structures, New York ISO (Rensselaer, NY)
Jim Gallagher, Director, Strategy, New York ISO (Rensselaer, NY)
Integrating Retail Dispatchable Demand Response and Dynamic Pricing in the Wholesale Markets

Increasing the participation of demand response in day-ahead and real-time energy markets plus ancillary markets is an objective to facilitate renewables integration and system operations. Increasing the amount of load that autonomously responds to energy prices on some basis is also desirable as a way to increase market efficiency and reduce extreme price volatility. This paper describes an ongoing project at the NY ISO that is exploring three critical aspects of increasing and integrating Dispatchable Demand Response and Dynamic Pricing. The first question is to more precisely identify the potential amounts and the performance characteristics of dispatchable demand response by end use application in the industrial, commercial, and residential sectors. The performance characteristics of interest include latency, duration, certainty, and fatigue factors. A related question is the quantification of demand elasticity and the same technical performance characteristics – how autonomous price response can be characterized in terms of time dynamics and changes in elasticity over time. The second question is how to realize the potential of Dispatchable Demand Response – what the technical roadmap is for each end use application in terms of communications, monitoring, and control. The third question is how the Dispatchable Demand Response and Dynamic Price response will integrate and interact in ISO energy and ancillary markets, given the technical performance characteristics of each element in the two resource groups. Key questions include impacts on market stability, price volatility, and the impact of errors and delays in information flow and in forecasting demand elasticity on market and system operations. For this purpose a representative dynamic model of market operations with the dynamics of Dispatchable Demand Response, Dynamic Price Response, and end user decision behavior is being to used to explore overall market behavior and identify unforeseen linkages and effects.

*Dhiman Chatterjee, Senior Manager, Market Process Improvement, Midwest ISO (Carmel, IN)
Addressing Real-Time Price Volatility in MISO Markets

MISO performs Security Constrained Economic Dispatch (SCED) every five minutes to clear the real-time market. Such frequent scheduling process provides opportunity to balance scheduling of supply resources against the energy and ancillary service requirements. However, it also leads to real-time market prices that are quite volatile with price spikes that may occur for a short period of time. These price spikes are predominantly attributed to limitation in the ability to ramp the necessary supply to satisfy both energy and ancillary service requirements. In some cases the ramp shortage is only transitory since committed resources are expected to be online a few minutes late. Unpredictable prices and inability to react to price changes lead to inadequate incentives for the resource owners so that resources are not offered with full flexibility that would assist MISO in managing operational challenges. Efficient provisioning of ramp for following of net load on a five minute dispatch frequency involves determination of requirements with careful consideration of variability and uncertainty associated with load, scheduled interchange, non-controllable generation and unanticipated deviation of controllable generation. It also requires capability to pre-position resources through probabilistic commitment and time-coupled dispatch processes. In addition, adaptive resource and constraint management and more efficient pricing mechanisms can reduce price uncertainty and provide incentives to resource owners at the same time. This presentation will provide an overview of a range of solutions being explored by MISO in order to address the price volatility observed in the real-time markets.

*Petar Ristanovic, VP of Technology, California ISO (Folsom, CA)
Managing Renewable and Distributed Resources' Intermittencies: Future Market and Software Enhancements

The electric industry faces many changes due ambitious environmental goals, maintaining grid reliability with fewer conventional plants, and cost containment strategies. This presentation discusses how ISOs can strike a balance between reliability, renewables, and reasonable cost. The current status of the California ISO market software is also presented.

Session C (Wednesday, June 29, 1:00 PM)

*Simon Tam, Manager, Markets Coordination, PJM Interconnection, L.L.C. (Norristown, PA)
Real-time Security-Constrained Economic Dispatch and Commitment in the PJM: Experiences and Challenges

This presentation will provide an overview of the practical experiences of implementing the new real-time Security-constrained Economic Dispatch engine and its supporting components. This new application employs a "time-coupled" optimization engine and is capable of producing multi-interval dispatch signal trajectories. When fully implemented, the dispatch base point volatility will be reduced resulting in enhanced market resource responses. The future real-time dispatch challenges include incorporating trend analysis into the optimization, more sophisticated adaptive resource modeling and automated

input data error detection/correction. The development of the operator visualization interface will also be discussed. PJM has designed and deployed the Perfect Dispatch application to closely observe and validate the real-time optimization performance. This presentation will review the benefits of the Perfect Dispatch process.

*Slava Maslennikov, Principal Analyst, ISO New England (Holyoke, MA)
*Kwok W. Cheung, Director, Automation Network Management Solutions, Alstom Grid, R&D (Redmond, WA)
Utilization of Adaptive Transmission Rates in Dispatch

The Adaptive Transmission Rating (ATR) concept initially proposed by ISO New England intends to safely increase the utilization of transfer capability of the power system by accounting for system's post-contingency ramping capabilities including post-contingency corrective actions. The effect is achieved via estimation of adaptive maximal values of emergency ratings, which can be safely used for enforcing post-contingency transmission constraints in dispatch instead of traditionally used fixed emergency rates. ATR addresses transmission constraints caused by thermal limitations only. Estimation of ATR requires complex calculations with modeling of power system post-contingency behavior during the time frame up to 30-60 minutes. The key component here is the estimation of the system Ramping Capability (RC). RC is the ability to change power flow in the specific transmission element by using available dispatchable resources and considering ramping constraints. Accurate estimation of RC requires to use components of dispatch software and market data, which are utilized in actual real-time dispatch. This presentation will discuss a joint ISO New England and ALSTOM R&D prototype implementation of ATR concept based on ALSTOM's EMS and Market system components. In order to allow operators to gain confidence of the ATR estimation, a prototyping tool called ATR Proof-of-Concept (POC) is implemented. The tool utilizes ALSTOM's SFT and SPD systems and uses real-time information from State Estimator, Contingency Analysis and Market system. The tool could act as an operator assistance to provide recommendation to system operators for limits of active transmission constraints in near real-time mode.

*Yonghong Chen, Consulting Engineer, Midwest ISO (Carmel, IN)
Paul Gribik, Senior Director, Market Development and Analysis, Midwest ISO (Carmel, IN)
Incorporating Reserve Deployment Impact on Transmission Constraints into Co-optimization of Energy and Ancillary Service Procurement

Under the current MISO Tariff, the deliverability of Operating Reserves is addressed by setting minimum zonal reserve requirements. After the start of the AS Market, MISO has determined that the deliverability of reserves is not fully addressed by the Tariff's existing approach. First, the deliverability of Regulating Reserves is not considered at all when establishing minimum Zonal Regulating Reserve Requirements. Second, even though an offline deliverability study is used to establish minimum Zonal Operating Reserve requirements, the scenario analyzed by the offline study 48 hours prior to the Operating Day can be very different from actual system operating conditions. As a result, Contingency Reserves procured based on the results of the offline study may be undeliverable if deployed to the extent that real-time conditions differ from the study's projections. Whenever such deliverability problems occur, MISO's real-time operators are forced to alleviate the resulting risk to system reliability by manually designating the

non-deliverable resources as "Not Qualified" to provide reserve products. Because of the above-described deliverability issues, a new approach is proposed to address the deliverability of reserves in the day-ahead and real-time market clearing and pricing processes. New transmission constraints are introduced into the co-optimization to evaluate the impact on transmission of the deployment of regulating, spinning and supplemental reserves on a zonal basis. Reserve zone requirements are solved to meet both market-wide reserve requirements and deliverability requirements. As a result, the approach introduces congestion components into zonal reserve Market Clearing Prices (MCPs). The new MCPs can properly reflect the effects of zonal reserve deployment on transmission constraints under consideration. With a proof of concept study, the performance impact on optimization solution is acceptable when a similar number of transmission constraints as used by offline study is considered in the co-optimization.

*Robert Entriken, Senior Project Manager, Electric Power Research Institute (Palo Alto, CA)
Taiyou Yong, Principle Consultant, Eversource Consulting (Folsom, CA)
Technique for Reserve Determination with Consideration for Conventional and Emerging Technologies: Enhancement of Stochastic Optimal Power Flow

Stochastic optimal power flow techniques have been used in formulating the reserve determination problem to address the issue of the increasing penetration of intermittent generation. Enhancements to the reserve determination model have been implemented in this report to accommodate the system ramping capability and coexistence of multiple random variables. In addition, risk measures are added into the solution report to provide a quantitative measure of risks of energy schedules. Market reserve validation and post-contingency fast re-dispatch have been illustrated in this report to demonstrate two immediate applications of reserve determination model. System operation and planning can use these applications to mitigate the system uncertainty and improve the system reliability.

Session D (Wednesday, June 29, 3:15 PM)

*Marianna Vaiman, Executive Vice President, V&R Energy (Los Angeles, CA)
Determining Optimal Mitigation Measures to Improve Transmission System Reliability in Real-Time

OPtimal Mitigation Measures (OPM) is a fast and efficient remedial actions software tool which allows its users to alleviate the post-contingency violations during massive N-1, N-1-1 and N-2 AC contingency analysis. The main purpose behind OPM is to be able to alleviate voltage, thermal and voltage stability violations identified as a result of performing AC contingency analysis, as well as to increase voltage stability margins and transfer capability. OPM may work in two modes: (1) identifying preventive actions; (2) identifying corrective actions. OPM optimizes both real and reactive sources in the system. Controls include: MW dispatch, MVAr dispatch, line switching, load curtailment, capacitor and reactor switching, transformer tap change, phase shifter adjustments. OPM is being extensively used to support real-time operations at Midwest ISO, ATC, NYPA and other utilities and integrated as a part of the real-time Smart Grid solution at ISO New England.

*anticipated speaker

*Daniel Bienstock, Professor, Columbia University (New York, NY)
Online Control of Cascading Power Failures

We describe ongoing work with real-time controls that shed demand adaptively so as to avert a cascading transmission system failure. In our model cascades are initiated by an exogenous contingency, and then followed by a sequence of outages that are caused by the power flow dynamics. We assume a control that is computed at time zero, and applied in real-time as the cascade unfolds, using system measurements (or estimations) as inputs. We will present simulations using systems with thousands of buses and lines.

*Pablo Ruiz, Associate Principal, Charles River Associate (Boston, MA)
Justin M. Foster, PhD Candidate, Boston University (Boston, MA)
Alex Rudkevich, Vice President, Charles River Associates (Boston, MA)
Michael C. Caramanis, Professor, Boston University (Boston, MA)
Tractable Transmission Topology Control

Today's economic generation dispatch (ED) and unit commitment (UC) practice assumes a practically constant transmission network topology. As a result, since Kirchoff's laws determine the specific line flows and very few lines have flow control devices, transmission line capacity constraints are maintained with the dispatch of generation out of its cost merit. Indeed, trading off appropriately located expensive generation against less costly but inappropriately located generation during congestion conditions is estimated to cause in the U.S. an additional generation cost of $4 to $8 billion per year. Topology Control (TC), i.e., appropriate changes of transmission line status, can redistribute power flow to significant lower congestion costs. Unfortunately, optimal TC for real-size networks is a computationally intractable Mixed Integer Programming (MIP) problem. This presentation will report on our promising recent work on tractable, albeit near optimal alternatives. By employing information readily available from the ED for a tentative network topology, we derive topology modifications that decrease congestion costs while maintaining reliability and system connectivity. Implementation of our algorithm on 100 scenarios (with different wind and fossil fuel generation mix) on the IEEE 118-bus test system demonstrated that of the 70% reduction in congestion cost that an optimal MIP algorithm showed on the average to be possible, our algorithm attained near-optimal network topologies that achieved a 65% cost reduction capturing 93% of the potential cost savings. Moreover, the computational effort was 3 to 4 orders of magnitude lower than that of MIP-based TC approaches.

*Thomas Dautel, Economist, Federal Energy Regulatory Commission (Washington, DC)
Richard O'Neill, Chief Economic Advisor, Federal Energy Regulatory Commission (Washington, DC)
AC Optimal Transmission Switching

When solving the AC optimal transmission switching problem, switches at both ends of each transmission line must be considered in order to achieve all potential benefits. A problem formulation is presented and solution techniques discussed.

Thursday, June 30

Session A (Thursday, June 30, 8:30 AM)

*Cong Liu, Postdoctoral Appointee, Argonne National Laboratory (Argonne, IL)
Jianhui Wang, Computing Engineer, Argonne National Laboratory (Argonne, IL)
Improving Static Security and Preventing Multiple Solutions in Transmission Switching

Transmission switching can improve the economic benefits of power system operations through changing its topology during operations. However, the switching operation itself represents a step change in power systems that is, to some extent, similar to a contingency. Although transmission switching is a type of scheduled, deterministic, discrete event, while the forced outage of a transmission line is a stochastic, uncontrollable, discrete event, both can introduce step disturbances into power systems. Security and reliability analyses are therefore needed to help prevent the adverse impacts on power system operations that can be brought about by transmission switching. In this talk, we will discuss security of transmission switching and present a new model for multi-period, static-security-constrained optimal transmission switching. The proposed model involves using disjunctive programming, which considers two sets of power flow equations under possibly different topologies before and after switching in each time interval. Each switchable transmission element is modeled into four states or disjunctions: (0) “stay offline,” (1) “stay online,” (2) “switch on,” and (3) “switch off.” State transition diagram coupling of four states in different hours is used to represent dynamic changes in topology. Our proposed model can also include contingency constraints based on N-1 reliability criterion. In addition, solving transmission switching may lead to multiple solutions of integer decision variables. The same unit commitment and economic dispatch may be feasible under different transmission switching schedules. In order to improve the reliability of power systems, we will introduce switching cost or a bi-level programming model that can lead to the less number of switching operations while ensuring the least operating cost.

*Kwok Cheung, R&D Director, Alstom Grid (Redmond, WA)
Optimal Transmission Switching: A Practical Assessment

Transmission elements are traditionally treated as non-dispatchable asset in the network. Co-optimizing transmission topology and generation dispatch could be a viable way to further maximize the market surplus and improve economic efficiency. This paper will discuss the mathematical formulation of optimal transmission switching. The benefit gain by deploying the transmission switching model will be assessed quantitatively. It is important to note that integer variables are introduced to model the on/off status of transmission elements. The number of integer variables being added to the mathematical formulation could be significant and hence impacts the computational performance. Some practical ways to reduce the size of integer variables are proposed. Some of proposed ideas are applied to a large-scale power system to assess the practicality and feasibility of optimal transmission switching.

*James Ostrowski, Postdoctoral Fellow, Argonne National Laboratory (Argonne, IL)
Jianhui Wang, Computing Engineer, Argonne National Laboratory (Argonne, IL)
Symmetry and Network Connectivity in Transmission Switching

Transmission switching provides a way to increase the efficiency in power systems operations by altering the topology of the transmission network. However, finding optimal solutions to the transmission switching problem can be very difficult. Fortunately, the transmission switching problem contains special structures that can be exploited during the optimization process. In this talk, we discuss two such structures, symmetry and reliability. Symmetry enters into the transmission switching problem when either identical generators are located at the same bus or when 2 or more identical transmission lines connect two buses. Symmetry has long been considered to be a major obstacle in optimization that often requires specialized methods. We present one such method that is able to exploit this symmetry, leading to significantly improved computational efficiency. Unfortunately, do to the complexity of the TS problem, it may not be practical to incorporate all of the desired reliability constraints, such as N-1 reliability. However, incorporating some reliability constraints may in fact improve the computational time needed to solve the TS problem. One such reliability constraint is anti-islanding. In this talk, we show how restricting the set possible transmission networks can lead to stronger optimization algorithms.

Session B (Thursday, June 30, 10:15 AM)

*Mark Lively, Consulting Engineer, Utility Economic Engineers (Gaithersburg, MD)
Real-Time Physical Markets—Within As Well As Between and Among Control Areas

Achieving real-time market efficiencies within a control area requires real-time markets between and among control areas. Without a real-time market between and among control areas any real-time market within the control area becomes a profit center for the control area. Profit centers within a control area are not bad. However, recent reports by Federal government labs have been using the lack of a real-time market between control areas to justify not requiring wind and other non-dispatchable resources to buy sufficient ancillary services to fulfill the contractual commitments they make to deliver electricity pursuant to a specific profile. Forcing control areas to participate in a physical real-time market with the other control areas will allow the control areas to enforce schedule commitments on a real-time basis. An advantage of a real-time physical market is that it will encourage the development of a plethora of storage options. Storage should operate contra-cyclically to troublesome loads and sources of generation. A real-time physical market would result in a net payment to any storage device operating contra-cyclically to problem devices.

*Linda Ness, Chief Scientist, Telcordia Applied Research (Piscataway, NJ)
Fast Multiscale Algorithms for Representation and Analysis of Streaming Data

A new suite of fast algorithms for computing and analyzing normalized multiscale representations of streaming and high-dimensional data will be presented. The research is joint between Telcordia (Devasis Bassu and Linda Ness) and Yale (Professors Peter Jones and Vladimir Rokhlin). The algorithms may enable a new methodology for rapidly characterizing uncertainty in power grid data, operational regimes and onset of failures.

*Marija Ilić, Founder and Owner, New Electricity Transmission Software Solutions (NETSS), Inc. (Sudbury, MA)
*Jeffrey Lang, Senior Consultant, New Electricity Transmission Software Solutions (NETSS), Inc. (Sudbury, MA)
Experience with AC Extended Optimal Power Flow (AC XOPF) on the New York System

In this talk we will report results of a major NYSERDA-funded study which was performed using real data system given to us by the NYISO. We report on the result of examining the optimization of the bulk NY transmission system with a focus on voltage dispatch. The insight gained through this optimization is useful for both planning and operations. Three separate optimization objectives are considered: the maximization of NYCA interface flows, the service of maximized load growth through the transfer of power over long distances through NYCA, and economic dispatch. Importantly, these optimizations are carried out while simultaneously dispatching voltage and T&D equipment (transformers and shunts), operating the system within both voltage and flow constraints, and balancing both real and reactive power. Many specific results will be available in the full NYSERDA report. In this talk we broadly summarize the results in several categories as discussed below.

Session C (Thursday, June 30, 1:00 PM)

*Vadim Shapiro, President, Statistics & Control, Inc. (West Des Moines, IA)
*Jeff Knollenberg, Statistics & Control, Inc. (West Des Moines, IA)
Dynamic Performance-Based Dispatch of Power Generation.

In cooperation with other control system providers, Statistics & Control has developed an advanced dispatch control system for a major global petroleum company's oil field. Because operations are isolated from the host nation's power grid, the company runs multiple power generation facilities that are fueled by natural gas captured from the oil field. Power and steam are transmitted to thousands of consumers throughout the enterprise micro-grid. Operations management wished to (1) centralize decision making and control for complete enterprise symbiosis of fuel, water, power, and steam and (2) optimize load sharing and transmission efficiency to reduce energy costs. This talk will focus on the power generation, transmission, and dispatching technology, which includes both hydraulic and electrical modeling of all producers, transmission, and consumers. The models are (1) transient to consider forecasted information and constraints, (2) interfaced to historical servers and control systems through OPC for real-time decisions and action, and (3) adaptive so that resources required to implement and maintain accuracy are minimized. By monitoring generation assets and by determining respective real-time performance characteristics, optimization based on current and forecasted conditions, loads, constraints, and objectives is possible. The optimal number of operating units and load distribution set points are provided in advisory or closed-loop format. "OptiRamp," the trademarked solution that was only recently commercialized, is being considered by multiple industrial cogeneration, university campus, and district energy operations. Applying this technology to the utility market would provide the decision capability for dispatching based on real-time performance economics and other objectives not currently employed. Additionally, transmission losses and strategic routing based on transmission loads can be considered, and intermittent supply from renewable

resources—e.g., wind turbines and PV panels—can be scheduled by interfacing with existing weather forecast algorithms.

*Nicolas Omont, Decision Mathematics Consultant, Artelys (Paris, France)
Towards the Implementation of Flow-Based Market Coupling in the Central Western Europe Region

Central Western Europe Market Coupling (CWE MC) is the project in which various Transmission System Operators (TSOs) and power exchanges are working to couple the Dutch, Luxembourgish, Belgian, French and German electricity markets. The ultimate aim of the project is to harmonise prices and create lower average prices across the region. With market coupling the cross border capacity between the various areas is not explicitly auctioned among the market parties, but is implicitly made available via energy transactions on the power exchanges on either side of the border (hence the term implicit auction). Market coupling in the CWE region ensures that the available cross border capacity is utilised more efficiently than with explicit auctions. The CWE MC project started as a market coupling system based on transmission capacity determined in a coordinated manner (Available Transfer Capacity Market Coupling, ATC MC). This interim step is necessary for the allocation of capacity on the basis of power flows (Flow Based Market Coupling, FB MC). This presentation will focus on the theoretical and experimental comparison of the efficiency of ATC MC and FB MC.

*Jinxiang Zhu, Sr. Principle Consultant, ABB Inc. (Raleigh, NC)
Day-Ahead Market Challenges to Production Simulation Tool

There are many challenges to model real markets, such as, dynamic rating, PAR settings, and ancillary services requirements, etc. Production simulation tool must take into consideration of the special operation requirements to mimic Day-Ahead market operation. Some examples are provided to show the solutions to challenges.

Session D (Thursday, June 30, 2:45 PM)

*John McNally, Director of Systems and Software, Energy Solutions, A123 Systems (Chesterfield, MO)
Increased Generator Flexibility through Distributed Software and Storage Assets

Storage provides new operational flexibilities for improving market efficiency, especially when coupled with advanced software. In addition to the physical components of its battery-based storage systems, A123 has also developed optimization algorithms for various improvements such as: - Increased energy output through coordinated operation with a thermal generator - Fast regulation services through standalone operation - Reduced uncertainty through renewable ramp management These applications run on an A123 Smart Grid Domain Controller (SGDC), a software platform located at the resource. The SGDC incorporates control center dispatch instructions and as local measurements in order to deliver the optimum response. Over the past year, the SGDC platform has accumulated significant operational records. This presentation will describe how resource-level software, in collaboration with system-wide optimizations, can contribute to general market efficiency.

*Jerry Dempsey, Vice President Sales and Marketing, Open Access Technology International (Minneapolis, MN)
Improving Real-Time and Intra-Hour Trading/Scheduling in Congested Bilateral Markets

As the bi-lateral markets expand to handle increased congestion and an influx of renewable generation, the need to improve intra-hour trading/scheduling is required. The presentation will explore how the entities within both Florida and the Western Interconnection bi-lateral markets have evolved to meet these challenges and prepare for future increased pressures. The challenge in these bi-lateral markets is the requirement to perform a manual and fragmented process for trading and scheduling within an ever decreasing timeframe. Each transaction must be traded in one platform, followed by securing of transmission rights on a second platform and completed with an e-Tag on a third platform. This process must be expedited to meet the challenges the markets are facing due to transmission constraints on increasingly congested electrical systems and a demand for sub-hourly scheduling to support renewable and intermittent resources. The presentation will describe how these challenges are being addressed. Within the Western Interconnection, the I-TAP will allow market participants to go from start to finish of a transaction in an expeditious manner, all on one platform in a largely automated environment which allows optimization of transmission, increased market transparency, and effective electronic scheduling. This will provide additional liquidity in the market and the ability to effectively respond to increasing scheduling frequencies (intra-hour). Within Florida, the Florida cost based broker system allows market participants to submit Bids and Offers for purchases and sales of electrical energy, then performs complex market clearing that matches posted bids and offers, creates electric energy transactions that provide savings to consumers while enforcing the transmission network limits, and automates the scheduling process including creation of OASIS Transmission Reservations and e-Tags. As these bi-lateral markets engage in increased renewable energy integration demanding more real-time trading and scheduling, expansion can provide more real-time market solutions for efficient transactions and physical scheduling. With these efficiencies transmission customers will gain flexibility to further increase renewable generation into to power grid that can handle intra-hour scheduling requirements, thereby improving the performance of the markets in the bi-lateral markets.

*Rouquia Djabali, Epex Spot sa (Paris, France)
Central West Europe Day-Ahead Market Coupling Algorithm

Market Coupling is both a mechanism for matching orders on the power exchanges and an implicit cross border capacity allocation mechanism. It improves the economic surplus of the coupled markets: the highest purchase orders and the lowest sale orders of the coupled power exchanges are matched, regardless of the market where they have been submitted and within the limit of the Available Transfer Capacity. The Market Coupling problem can be modeled as a mixed integer quadratic problem and solved with heuristics or exact methods. Qualitative and quantitative results of the algorithm designed and implemented for the CWE Market Coupling, in production since the 9th November 2010, are presented and discussed.
http://static.epexspot.com/document/9606/COSMOS_public_description.pdf

*Anya Castillo, Operations Research Analyst, Federal Energy Regulatory Commission (Washington, DC) and PhD Candidate, Environmental Engineering at Johns Hopkins University (Baltimore, MD)
Richard O'Neill, Chief Economic Advisor, Federal Energy Regulatory Commission (Washington, DC)
Michael Higgins, Economist, Federal Energy Regulatory Commission (Washington, DC)
Computational Approaches to the AC Optimal Power Flow (AC OPF) Problem

Recent advances in computational power have made nonconvex AC optimal power flow (AC OPF) models more tractable. In this talk we will review the polar and rectangular formulations of the AC OPF problem and present ongoing analysis of IEEE test cases.

*anticipated speaker